Influence of Hunger on Sweetness Preferences and Taste Thresholds

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THE SENSE of taste and food preferences are undoubtedly influenced by body chemistry. However, little is known about the psychologic, physiologic, and chemical interactions which regulate the sense of taste and consequent qualitative and quantitative food selection. The first part of the present paper describes the relationship between hunger and sweetness preferences of 11,456 consumers. The second investigation involves the taste thresholds and sweetness preferences of a highly trained panel of eight judges under fasting and nonfasting conditions.

REVIEW

The "glucostatic" theory is frequently discussed in the literature. This theory concerns the controversial hypotheses of regulation of food intake based upon the fact that blood glucose concentrations rise and arteriovenous differences increase following ingestion of meals containing carbohydrates and proteins.[1] In tests on human subjects, Mayer[2] has found evidence for a relationship between blood glucose levels and hunger, appetite, or food intake. Albanese[3] has reported that approximately 30 g or 120 calories of sugar are needed to hurdle the postulated hunger threshold in the average 70-kg man. This investigator speculated that there might be a correlation between blood amino nitrogen and hunger and food intake, since fructose-containing sugars induced a greater blood amino nitrogen change than did comparable amounts of dextrose in fasting human subjects.[4]

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McCleary[5] associated osmotic pressure with specific hunger behavior, since preloading the stomachs of rats with glucose, fructose, urea, or sodium chloride resulted in depression of ingestion proportional to osmotic pressure.

According to Pfaffman and Bare,[6] salt deficiency did not alter the sensitivity of the taste receptors. Furthermore, enhanced sugar preference following the ingestion of insulin was not associated with a change in taste sensitivity.[7] Young[8] feels that food preferences definitely depend upon the diet, since protein-deficient rats preferred casein to sucrose, whereas rats on an adequate protein diet preferred sucrose.

Yensen[9] placed two human subjects on a low-salt diet and observed that during the periods of salt deficiency taste sensitivity for sodium chloride definitely increased, while sensitivity to sucrose, sulfuric acid, and quinine sulfate showed no change. In experiments with 70 human subjects, Siegel[10] concluded that there was a stronger relationship between hunger and palatability than between hunger and intake.

Olfactory acuity of human subjects has shown diurnal variations which are closely dependent upon food ingestion. Freely selected meals by human subjects were preceded by a period of increasing and followed by one of decreasing acuity.[11] These authors suggested that the precibal increase in olfactory acuity might be a measure of appetite intensity, whereas postcibal decrease in acuity might be a measure of satiety afforded by food ingested. Later work[12] verified their postulation; freely selected meals by 2 males and 14 females were preceded by a period of increasing and followed by one of decreasing acuity of the sense of taste for sucrose. Janowitz and Grossman,[13] however, reported only minor variations in acuity of the sense of

taste for sucrose and sodium chloride as well as the threshold for the odor of coffee, bearing no consistent relation to the presence or absence of hunger sensations and appetite. It should be mentioned that in the foregoing experiment there was but one test day for each subject.

The effects of withholding lunch and controlling the food intake at breakfast, on sucrose (gustatory) and isoamyl acetate (olfactory) thresholds have been reported by Furchtgott.[14] Gustatory thresholds were lower when no lunch was eaten than after lunch, whereas olfactory thresholds were not affected.

The accuracy of responses from professional tasters of alcoholic beverages was found to be highest during the half-hour before lunch and the half-hour immediately after lunch.[15] This investigator stated, " . . . although eating per se may dull the sensory receptiveness, other physical or psychological factors counteract this to the extent of making the period immediately after lunch better than most of the other times of day." In the foregoing case, accuracy increased with practice, then decreased due to fatigue.

Birch *et al.*[16] made the interesting observation that in rats the drive for food was not an increasing function of hours of deprivation, but that the function rose to a maximum at the accustomed time of feeding, then decreased with increased deprivation.

In an excellent review, Young[17] concluded that there were three complexly interrelated conditions which regulate food acceptance: conditions within the organism (appetite); conditions within the nutritive environment (palatability); conditions within the previous behavior of an organism (feeding habit).

METHODS AND MATERIALS

Consumer Study

The 1957 California State Fair, held in Sacramento from August 28 through September 8, was the location for interviewing 11,456 individuals. Several investigators have used the Fair population to determine sweetness preferences in wines, ice cream, and canned peaches with good reproducibility of results from year to year.[18–24]

Samples of Johnson cling peaches, varying in sucrose and/or total acidity (Table I) and packed under carefully controlled conditions in the pilot plant of the Food Technology Department, Davis, were evaluated.

TABLE I

Sucrose and Citric Acid Content of Canned Cling Peaches

Sample code	Soluble solids[a]	Total acidity[b]	pH
A	24.24	0.279	4.06
B	26.98	0.277	4.12
C	27.59	0.408	3.78
D	26.95	0.561	3.52
E	31.20	0.427	3.73
F	31.51	0.553	3.52
G	36.77	0.548	3.55

[a] Soluble solids of the pulped peaches plus syrup determined by refractometry and expressed as ° Brix.
[b] Expressed as per cent citric acid anhydride.

The peach-tasting booth, open to the general public from 10:30 A.M. to 8 P.M., consisted of 6 individual, partitioned windows through which samples were served. Children under 12 years of age were admitted if accompanied by an adult. Participants were met by a receptionist who recorded their sex, age, and frequency of consumption of canned peaches. Each consumer was given a score card and instructed to check the category which best described his state of hunger at that exact time.

1. ____I am extremely hungry
2. ____I am very hungry
3. ____I am moderately hungry
4. ____I am slightly hungry
5. ____I am not hungry at all

The above terminology was an adaptation of a scale described by Siegel.[10]

The participant then received two 4-oz samples of cold, diced peaches in cups coded "1" and "2" and was asked to check his preference. A "no preference" response was allowed. Care was taken to present the 21 possible paired comparisons an equal number of times; for each combination, the order of presentation was reversed in half the cases to compensate for any first-sample bias.

Laboratory Study

Four female and four male college students between 19 and 24 years of age were employed on a laboratory taste panel which met from 4:30 to 5:30 P.M. Monday through Thursday for 10 consecutive weeks. Good health, age, interest, and dependability were the only criteria used in selection of the panel.

All tests were designed so that four judges could serve the other four tasters who were seated in individual, partitioned booths equipped with constant lighting, temperature, and humidity. Upon completion of 5 to 10 minutes of tasting, the judges alternated sides, thereby reducing fatigue and monotony.

The first two weeks were spent in thoroughly acquainting the judges with the methods of tasting and training them to recognize small concentrations of sweetness, sourness, bitterness, and saltiness in aqueous solutions.

Thresholds for sucrose, sodium chloride, citric acid, and caffeine (reagent grades) were determined by the "choice method" of Richter and MacLean.[25] Subjects were presented with a labeled 100-ml beaker of tasteless, odorless, freshly distilled water to be compared against samples containing varying amounts of the compound being tested. Judges were allowed to sample the fluids in each beaker as often as they desired. Fountains in the booths provided for expectoration and only freshly distilled water was allowed for oral rinsing at the taster's discretion. Judges were instructed to indicate whether the paired solutions tasted identical or different and to identify the taste in terms of "sour, bitter, sweet, or salty." Solutions were presented at the rate of one per minute until two successive correct identifications were obtained. Servers introduced a distilled water blank (*Vexierversuche*) once or twice during a series. Tasters and servers were under constant supervision to assure uniformity of conditions. To eliminate guessing, fluids were kept in numerically coded containers and served in coded beakers, and series were randomized, i.e., same or different compounds could be submitted to each subject on any one day.

Original concentrations of the test compounds were as follows: Sucrose: 0.006, 0.012, 0.018, 0.024, 0.030, 0.036, 0.042, 0.048 M; citric acid: 0.0001, 0.0006, 0.0011, 0.0016, 0.0021, 0.0026, 0.0031, 0.0036 M; sodium chloride: 0.001, 0.007, 0.013, 0.020, 0.027, 0.034, 0.041, 0.048 M; caffeine: 0.0001, 0.0006, 0.0011, 0.0016, 0.0021, 0.0026, 0.0031, 0.0036 M.

As the judges' acuity increased with practice, the concentrations were adjusted accordingly until the final solutions were: Sucrose: 0.0008 to 0.022 M; citric acid: 0.000008 to 0.0002 M; sodium chloride: 0.0006 to 0.0300 M; caffeine: 0.00006 to 0.0008 M.

Each day, after all judges had completed the threshold series, apricot nectar varying in sweetness (8, 9, 10, 11, or 12 per cent sucrose) was tasted in paired sets and preference indicated. Since a "no preference" response was not permitted, judges were forced to make a choice. The 10 possible paired comparisons were presented an equal number of times in numerically coded 50-ml beakers.

TABLE II

Classification of Responses to Hunger

Classification	Degree of hunger (% of responses)					Total participation
	Extremely	Very	Moderately	Slightly	Not at all	
Sex						
Male	10.2	12.5	34.1	34.9	8.3	5,478
Female	6.1	11.1	32.2	38.4	12.2	5,978
Age						
Under 16	11.6	16.0	27.4	38.3	6.7	4,395
16–24	7.1	10.4	36.6	34.8	11.1	1,936
25–39	3.8	8.2	38.1	37.4	12.5	2,699
40–60	6.1	8.5	35.8	35.1	14.5	1,943
Over 60	11.8	11.2	32.5	32.5	12.0	483
TOTAL	8.1	11.7	33.1	36.7	10.4	11,456

TABLE III

Effect of Hunger on Peach Preference

Significant preferences only

Pair		Degree of hunger									
		Extremely		Very		Moderately		Slightly		Not at all	
1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A	B	—	—	—	—	—	—	132[a]	88	—	—
A	C	—	—	—	—	—	—	—	—	—	—
A	D	—	—	—	—	—	—	—	—	—	—
A	E	—	—	—	—	—	—	—	—	—	—
A	F	—	—	—	—	92[c]	65	—	—	—	—
A	G	—	—	—	—	102[a]	63	136[b]	55	30[c]	16
B	C	—	—	20	46[a]	—	—	—	—	—	—
B	D	—	—	—	—	—	—	—	—	—	—
B	E	—	—	—	—	—	—	—	—	—	—
B	F	—	—	—	—	—	—	—	—	—	—
B	G	27[a]	10	54[b]	18	125[b]	44	146[b]	49	—	—
C	D	—	—	—	—	—	—	—	—	—	—
C	E	—	—	—	—	—	—	—	—	—	—
C	F	—	—	—	—	—	—	—	—	—	—
C	G	—	—	53[b]	17	126[b]	52	140[b]	68	41[c]	23
D	E	—	—	—	—	—	—	—	—	—	—
D	F	—	—	—	—	—	—	—	—	—	—
D	G	—	—	52[b]	19	138[b]	57	121[b]	59	32[c]	17
E	F	—	—	—	—	—	—	—	—	—	—
E	G	—	—	—	—	126[b]	47	139[b]	70	39[b]	14
F	G	—	—	—	—	137[b]	44	134[b]	63	—	—

[a] Significant at 1% level of probability. [b] Significant at 0.1% level of probability. [c] Significant at 5% level of probability.

The experimental conditions of fasting were not initiated until each judge had ceased to improve in acuity with practice. At this time, a schedule was effected in which the students consumed their usual meals in the dormitory dining facilities except that on alternate days no food or liquid (except water) was allowed between breakfast and the test hour (4:30 P.M.). A check of their normal eating habits showed that all subjects were accustomed to a moderate, fairly standardized breakfast (eggs, juice, toast, milk, coffee) and a light lunch (sandwich, salad, fruit, milk). Subjects attended classes and participated in extracurricular activities as usual during the 10-week experiment.

RESULTS AND DISCUSSION

Consumer Survey

Classification of the peach tasters (Table II) showed that more females than males participated and that a slightly different pattern of response was evident between the sexes. Fewer females than males were "extremely hungry," whereas fewer males than females were "not hungry." Consumers under 16 and those over 60 gave the most frequent "extremely hungry" responses. Regardless of age or sex, the majority of the population sampled was slightly to moderately hungry prior to sampling the fruit.

Table III summarizes the peach preferences with values presented only for the significant combinations. It is immediately apparent that sample G, which was extremely sweet and highly acidified, was inferior to all other samples. Only one significant preference was obtained from the extremely hungry tasters, suggesting that extreme hunger decreases discrimination. One could speculate also that individuals who were not hungry at all might tend to have no preference, since neither sample would appeal to them. The data showed that 6.9 per cent of the "not hungry" group and 7.5 per cent of the "extremely hungry" group indicated no preferences, whereas "very," "moderately," and "slightly hungry" consumers gave no preference answers in 5.0,

TABLE IV

Hunger and Sweetness Preference in Apricot Nectar[a]

Classification and sex	Sample and % sucrose A 8.0	B 9.0	C 10.0	D 11.0	E 12.0	No. paired comparisons
Not Fasting						
Males	8	18	25	33	44	
Females	16	15	26	36	35	
TOTAL	24	33	51	69	79	256
Fasting						
Males	10	18	28	37	35	
Females	10	24	22	30	34	
TOTAL	20	42	50	67	69	248

[a] Values represent total comparative preferences for paired samples.

3.7, and 4.6 per cent of the total responses, respectively. The over-all preference was little if at all affected by hunger. If a quantitative measure of the peaches consumed could have been recorded, the results would undoubtedly have differed from the qualitative responses collected.

Laboratory Panel

Apricot Nectar Preferences: Hunger had little effect on total comparative preferences for sweetness in apricot nectar (Table IV). To determine whether fasting affected individual panel members, the frequency with which tasters preferred sweeter samples, regardless of sugar increment, was determined (Table V). Although judges differed from each other in their responses, only one subject (S.M.) demon-

TABLE V

Individual Responses to Sweetness in Apricot Nectar

Sex and subject	Preference for sweeter sample[a] Not fasting (%)	Fasting (%)
Males		
W. M.	71.9	81.3
K. S.	75.0	68.8
R. T.	96.9	93.8
K. Z.	75.0	75.0
AVERAGE	79.7	79.7
Females		
S. M.	40.6	59.4
J. C.	87.5	87.5
A. R.	84.4	75.0
C. W.	81.3	78.1
AVERAGE	73.4	75.0
GRAND AVERAGE	76.6	77.4

[a] Individual percentages represent 32 separate paired evaluations.

TABLE VI

Effect of Training on Taste Thresholds

Comparison of first and sixth determination

Subject	Sucrose 1st	Sucrose 6th	Citric 1st	Citric 6th	NaCl 1st	NaCl 6th	Caffeine 1st	Caffeine 6th
	MOLARITY							
Males								
W. M.	0.036	0.022	0.00160	0.00010	0.034	0.030	0.00160	0.00020
K. S.	0.024	0.008	0.00060	0.00004	0.013	0.003	0.00060	0.00008
R. T.	0.036	0.008	0.00210	0.00001	0.034	0.005	0.00160	0.00040
K. Z.	0.018	0.010	0.00110	0.00010	0.020	0.003	0.00110	0.00060
Females								
S. M.	0.012	0.006	0.00060	0.00001	0.020	0.007	0.00060	0.00040
J. C.	0.018	0.002	0.00010	0.00003	0.020	0.005	0.00110	0.00030
A. R.	0.018	0.006	0.00210	0.00004	0.007	0.003	0.00310	0.00060
C. W.	0.018	0.004	0.00110	0.00003	0.020	0.009	0.00160	0.00060
GROUP AVERAGE	0.022	0.008	0.00116	0.00005	0.021	0.008	0.00141	0.00040

TABLE VII
Individual Identification Thresholds

Sex and subject	Sucrose		NaCl		Citric acid		Caffeine	
	Not fasting	Fasting	Not fasting	Fasting[a]	Not fasting	Fasting	Not fasting	Fasting
	MOLARITY × 10^{-4}							
Male								
W. M.	40	160	110	100	0.6	0.2	5.0	5.0
K. S.	60	40	40	50	0.3	0.1	0.7	3.0
R. T.	90	50	60	7	0.3	0.2	1.9	1.0
K. Z.	70	80	70	60	0.4	0.1	6.0	8.0
AVERAGE	70	81	62	57	0.4	0.2	4.2	4.2
Female								
S. M.	40	50	70	10	0.3	0.2	2.3	4.0
J. C.	9	9	20	50	0.2	0.2	2.4	0.8
A. R.	60	70	30	30	0.2	0.6	6.0	4.0
C. W.	90	20	50	30	0.1	0.2	4.0	1.9
AVERAGE	46	37	34	21	0.2	0.3	3.7	2.5
GRAND AVERAGE	60	60	50	40	0.3	0.2	4.0	3.0

[a] Significant difference between male and female responses to NaCl at the 5% level of probability.

strated an increase in preference for the sweeter sample with hunger. In general, regardless of method of classification, hunger did not affect sweetness preferences.

Taste Thresholds: Blakeslee's statement, "Different people live in different worlds so far as their sensory reactions are concerned,"[26] is well-demonstrated in Table VI. Four important conclusions can be derived from these data: (a) wide variation between individuals; (b) decided decrease in all thresholds with practice; (c) wide variation between individuals in degree of improvement with practice; (d) much lower original as well as final thresholds shown by females as a group than by males.

Threshold values reported for determination 1 are within the range of thresholds reported in the literature. Knowles and Johnson[27] published values of 0.003 M, 0.0224 M, and 0.05 M for low, medium, and high sucrose thresholds, respectively. For citric acid, Fabian and Blum[28] list a value of 0.0007 M. According to Richter and Campbell,[29] humans first recognize the taste of sodium chloride in solution at 0.065 per cent (0.011 M). Threshold values for caffeine have been observed at 0.0002 M to 0.0032 M.[13] With the exception of the caffeine thresholds, training subjects resulted in lower final thresholds than the literature values reported above.

TABLE VIII
Hunger and Taste Thresholds

Compound and condition	No. judgments	Average difference threshold	Average identification threshold
		MOLARITY × 10^{-4}	
Sucrose			
Not fasting	18	50	60
Fasting	16	30	60
NaCl			
Not fasting	18	30	50
Fasting	16	20	40
Citric acid			
Not fasting	16	0.3	0.3
Fasting	15	0.2	0.2
Caffeine			
Not fasting	16	3.0	4.0
Fasting	15	3.0	3.0

Since there were only minor fluctuations in thresholds after the sixth set of determinations, the fasting vs. nonfasting experiment commenced with the eighth determination to give the results shown in Table VII. Average panel values showed no variation as a result of fasting, thereby agreeing with results obtained by Janowitz and Grossman.[13] Females seemed to be slightly more sensitive to the compounds when they were hungry than were males. Only one subject (R.T.) was consistently more sensitive to all compounds when fasting. It is of interest that the only statistically different values ob-

tained were between male and female responses to sodium chloride.

A comparison between the average difference thresholds and the average identification thresholds is made in Table VIII. There is a slight, but not significant, trend for lower thresholds under fasting conditions. Except for citric acid, a difference was established between plain water and the compound in solution before the correct identification could be made.

SUMMARY

No relationship was observed between degree of hunger and sweetness preferences in canned cling peaches as evaluated by 11,456 consumers under uncontrolled conditions. Similar results were obtained from a highly trained laboratory panel of eight judges tasting sweetened apricot nectar. In addition, fasting vs. nonfasting conditions had no pronounced effect on difference thresholds nor upon identification thresholds for sucrose, citric acid, sodium chloride, or caffeine. Taste thresholds for all four compounds were significantly reduced with training. Female judges, as a group, were more sensitive than were the males.

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Tell me what you eat, and I will tell you what you are.
—A. BRILLAT-SAVARIN